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REMARKS

Applicants respectfully request reconsideration of the present application in view of the foregoing amendments and in view of the reasons which follow.

Claims 1, 3, 10, 13, and 15 are currently being amended.

After amending the claims as set forth above, claims 1-20 are now pending in this application.

This amendment adds, changes and/or deletes claims in this application. A detailed listing of all claims that are, or were, in the application, irrespective of whether the claim(s) remain under examination in the application, are presented, with an appropriate defined status identifier.

Rejections Under 35 U.S.C. § 102

Claims 1-7, 9-13, 15-17, and 19-20 are rejected under 35 U.S.C. § 102(e) as being anticipated by U.S. Patent No. 6,268,291 (Andricacos et al.). Applicants respectfully traverse the rejection. Andricacos et al. does not disclose the claimed invention as recited in Claims 1-7, 9-13, 15-17, and 19-20.

Claim 1 requires:

> implanting a metal into the barrier material layer at a implantation energy of 5.0 keV or less,

Claim 10 requires:

> amorphizing the barrier material layer by implanting a metal into the barrier material layer at a implantation energy of 5.0 keV or less,

Claim 15 requires:

> implanting a metal species into the barrier material layer at a implantation energy of 5.0 keV or less,

Claims 2-7 and 9 depend from claim 1. Claims 11-13 depend from claim 10. Claims 16-17 and 19-20 depend from claim 15.

Andricacos et al. describes a method of adding impurities into a copper composition to improve electromigration resistance. (See Abstract.) Impurities or "dopants" suggested by Andricacos et al. include non-metals, such as C, O, Cl, S, and N (see Col. 11, lines 6-7) as well as metals, such as Ti, Al, Sn, and In (see Col. 13, lines 12-24). Andricacos et al. teaches implantation energies and dosages for implanting these impurities. The ***non-metal*** dopants "are typically implanted at various energies ranging from a few keV to several hundred keV, for instance, from 10 keV to about 600 keV." (Col. 11, lines 8-11.) However, the ***metal*** dopants are implanted at energies ranging from 90 keV to 180 keV. (See Table 4, Col. 13, lines 16-24.)

As explained in Col. 6, line 66 through Col. 7, line 16, Andricacos et al. teaches a "dual-implantation process" in which non-metal dopants are implanted into the copper conductor and then a ***surface layer*** is ion implanted with a second dopant (either non-metal or metal). Andricacos et al. touts that this dual implantation process helps with adhesion with layers on top of the copper conductor and helps with a "decrease in the copper surface diffusively." (Col. 7, lines 7-11.) Andricacos et al. specifically states: "The metal ions chosen for the secondary surface implantation process have high affinity for oxygen such that the ions segregate to the copper interface (or surface) to form metal oxides as a protective layer for the copper conductor." (Col. 7, lines 11-16.)

Andricacos et al. does not disclose the limitations of claims 1-7, 9-13, 15-17, and 19-20 because Andricacos et al. does not teach implanting a metal ***into*** a barrier material layer and, *when a metal dopant is used in Andricacos et al. to form a* ***surface layer****, it is implanted at energy levels between 90 keV and 180 keV.* There is no suggestion in Andricacos et al. that a metal be implanted into a barrier. Further, there is no suggestion in Andricacos et al. that a much less energy level be used for implanting metal ions.

Prior art must disclose each and every limitation in a claim for the claim to be anticipated. Andricacos et al. does not disclose each and every limitation of Claims 1-7, 9-

13, 15-17, and 19-20. Accordingly, Applicants respectfully request withdrawal of the rejection.

Claims 10 and 14 are rejected under 35 U.S.C. § 102(b) as being anticipated by U.S. Patent No. 5,899,740 (Kwon). Applicants respectfully traverse the rejection. Kwon does not disclose the claimed invention as recited in Claims 10 and 14.

Claim 10 recites:

> amorphizing the barrier material layer by implanting a metal into the barrier material layer at a implantation energy of 5.0 keV or less,

Kwon describes a method of making copper interconnects. Kwon teaches that an amorphous diffusion barrier can be used where the amorphizing is "performed by implanting ions into the diffusion-barrier film." (See Abstract.) Col. 2, lines 14-24 of Kwon teaches the amorphizing step as follows:

> The amorphizing step is preferably performed by implanting ions into the diffusion-barrier film to create an amorphous diffusion-barrier film. The diffusion-barrier film is preferably formed from at least one material selected from the group consisting of Mo, W, Ti, Wn, TiW, TiN and may be formed by chemical vapor deposition. **The ions which are implanted are preferably selected from the group consisting of boron, nitrogen and silicon ions**. A second diffusion-barrier film may also be formed on the copper film opposite the earlier formed amorphous diffusion-barrier film. The second film may also be amorphized as described above.

(emphasis added.)

Thus, Kwon does not teach "amorphizing the barrier material layer by implanting a metal into the barrier material layer at a implantation energy of 5.0 keV or less," as required by both claim 10 and 14. Kwon teaches implanting boron, nitrogen, or silicon ions into a film. None of these ions are metals. Further, the energy level used to implant B, N, or Si taught by Kwon is 20-140 keV. (See Col. 4, lines 3-7.)

As mentioned above, prior art must disclose each and every limitation in a claim for the claim to be anticipated. Kwon does not disclose each and every limitation of Claims 10 and 14. Accordingly, Applicants respectfully request withdrawal of the rejection.

Rejections Under 35 U.S.C. § 103

Claims 8 and 18 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Andricacos et al. in view of U.S. Patent No. 6,426,289 (Farrar). Applicants respectfully traverse the rejection. Andricacos et al. and Farrar do not disclose, suggest, or teach the claimed invention as recited in Claims 8 and 18.

Claim 8 recites:

> The method of claim 1, wherein the barrier material layer has a size of a thickness of between 10 and 300 Angstroms.

Claim 18 recites:

> The method of claim 15, wherein the metal species is implanted at a dose of $2e^{14}$ to $2e^{15}/cm^2$ at an energy of 0.5 to 5 keV.

Claim 8 depends from and includes all the limitations of claim 1. Claim 18 depends from and includes all of the limitations of claim 15. As described above, Andricacos et al. does not disclose, suggest, or teach all of the limitations of claim 1 or 15.

Farrar describes a method of making a barrier layer, but describes a barrier layer that is **5 to 40 Angstroms thick** and is implanted with ions at a **concentration of 1.25 x 10^{16} ions/cm^2 to 2.0 x 10^{17} ions/cm^2**. Specifically, Farrar teaches:

> Preferably, the zirconium is implanted at an energy of about 0.5 keV and at a concentration of about $5x10^{16}$ ions/cm^2. For the other possible dopants, the implant energy and the concentration can be about 0.125 to about 2.0 keV and about $1.25x10^{16}$ to about $2.0x10^{17}$ ions/cm^2, respectively without deviating significantly from the spirit of the invention. Preferably, top barrier layer 13a is about 5 A to 40 A thick and more preferably around 20 A thick.

(Col. 4, lines 28-38.)

Andricacos et al. describes metal ions being implanted to create a surface layer. As described above, implanting metal ions to create a surface layer is not the same as "implanting into the barrier material layer" as required by claim 1 from which claim 8 depends. Moreover, Andricacos et al. does not provide any thickness for barrier layer 94. Thus, neither Farrar nor Andricacos et al. alone or in combination disclose the **barrier layer thickness limitation** of claim 8. Applicants respectfully request withdrawal of the rejection of claim 8.

Andricacos et al. provides dosage values for metal ions used in Table 4 in Col. 13, lines 15-24. Of the metal ions listed in the Table, all the dosages are "3E15." Thus, neither Farrar nor Andricacos et al. alone or in combination disclose the **implantation dosage limitations** of claim 18. Farrar and Andricacos et al. also fail to disclose, suggest, or teach the limitations in claim 15 from which claim 18 depends. Applicants respectfully request withdrawal of the rejection of claim 18.

Applicant believes that the present application is now in condition for allowance. Favorable reconsideration of the application as amended is respectfully requested.

The Examiner is invited to contact the undersigned by telephone if it is felt that a telephone interview would advance the prosecution of the present application.

The Commissioner is hereby authorized to charge any additional fees which may be required regarding this application under 37 C.F.R. §§ 1.16-1.17, or credit any overpayment, to Deposit Account No. 06-1447. Should no proper payment be enclosed herewith, as by a check being in the wrong amount, unsigned, post-dated, otherwise improper or informal or even entirely missing, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 06-1447. If any extensions of time are needed for timely acceptance of papers submitted herewith, applicant hereby petitions for such extension under 37 C.F.R. §1.136 and authorizes payment of any such extensions fees to Deposit Account No. 06-1447.

Respectfully submitted,

Date June 2, 2003 By

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